

METHOD FOR DETERMINING A COVERAGE AREA IN A CELL-BASED
COMMUNICATION SYSTEM

Field of the Invention

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This invention relates to determining the coverage of a cell in a cell-based communication system. The invention is applicable to, but not limited to, utilising such coverage information to assist alarm prioritisation due to cell outage and/or re-configure a system's or cell's operational parameters to minimise the degree of overlapping coverage, thereby allowing higher capacity/quality frequency plans to be deployed.

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15 Background of the Invention

Wireless communication systems, for example cellular telephony or private mobile radio communication systems, typically provide for radio telecommunication links to be arranged between a plurality of base transceiver stations (BTSs) and a plurality of subscriber units, often termed mobile stations (MSs).

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In a wireless communication system, each BTS has associated with it a particular geographical coverage area (or cell). Primarily, a particular transmitter power level defines a coverage area where a BTS can maintain acceptable communications with MSs operating within its serving cell. In addition, receiver sensitivity performance of receiving wireless communication units also affects a given coverage area. In large cellular communication systems, these cells are combined and often overlapped to produce an extensive coverage area.

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Wireless communication systems are distinguished over fixed communication systems, such as the public switched telephone network (PSTN), principally in that mobile
5 stations move between coverage areas served by different BTS (and/or different service providers) and, in doing so, encounter varying radio propagation environments.

In a cellular system, adjacent cells are typically
10 configured to overlap, to ensure a contiguous signal coverage area. The cell overlap region is deliberately designed into the system plan to ensure that mobile stations can successfully handover between cells. The degree of coverage overlap between cells can vary
15 enormously. In such systems it is desirable to have an accurate measure of unique cell coverage (and ideally cell overlap) to operate and maintain the network more effectively (i.e. maximising capacity and quality of service).

20 A system design based on cells is typically based on an ideal cell pattern. However, an idealised cell pattern never occurs in practice, due to the nature of the terrain and the fact that cell sites and antennae are not
25 ideally located on a regular grid pattern. The network designer therefore uses frequency planning tools to estimate the radio propagation for each cell and predict a corresponding coverage area. Based on these propagation models, the network designer is able to
30 develop a frequency plan for the network intended to minimise the expected interference. The frequency plan considers such factors as antenna heights and location, terrain topology, transmitted power levels and the anticipated number of subscribers.

By collating predicted coverage area information for a number of cells, it is possible to determine a degree of coverage overlap between a number of respective cells.

5 However, the accuracy of these tools is limited, since they 'predict' the theoretical coverage rather than measure the actual coverage supported by a particular BTS.

10 The quality of a frequency plan that can be produced by such coverage prediction techniques is constrained by the degree of coverage overlap between cells. Greater overlap means greater potential interference, making it more difficult to produce a low interference frequency

15 plan. A traditional method of allocating frequencies in a wireless cellular system is to employ a channel allocation algorithm in conjunction with a carrier-to-interference (C/I) matrix, where the C/I matrix may use measurement report data.

20 Achieving an optimum frequency plan is therefore dependent on the C/I matrix accuracy, and it is inaccuracies in these matrices that ultimately lead to unexpected interference. There are a number of reasons

25 why traditionally produced matrices are inaccurate. For example, the matrices are based on predicted interference levels at ground level, i.e. subscribers in high buildings are not considered. They assume fixed cell boundaries whereas the characteristics of MSs and

30 handover algorithms are such that cell boundaries can move. Also, they are reliant on accurate site and antenna data. This data can be far from accurate with some Operators having no clear idea of where their sites are, let alone being confident in the bore angles of the

antennas. They do not reflect the impact of detailed clutter data, such as street canyons.

Furthermore, these coverage prediction techniques tend to
5 focus on geographic coverage area, assuming an even distribution of MSs within the cell, rather than subscriber-based coverage where subscribers are unevenly distributed across a cell. This inaccuracy limits the effectiveness of the predictions and the resulting
10 decisions made therefrom. This, in turn, means that the network is sub-optimally configured and therefore typically delivers a sub-optimal quality of service.

The inventors of the present invention have therefore
15 both recognised and appreciated that there is currently no accurate method of determining an accurate cell-based coverage map, particularly when there exists coverage overlap between cells.

20 In the context of network optimisation, it is known that measurement reports are collected from an operational network, as described in co-pending UK Patent Application GB 9926513.4 having the same Applicant as the present invention. The data collected is then analysed to
25 generate neighbour cell list for handover purposes and facilitate power control decisions. In this regard, it is known that MSs scan signal transmissions from multiple BTSs and report the signal levels of these in the measurement reports. The scanning process, which is used
30 to generate the measurement reports, enables the MS (or its serving BTS) to determine optimal handover candidates, namely the BTS offering the highest quality signal/communication link to the respective MS.

Thus, there exists a need in the field of the present invention to provide a cell-based communication system and method for determining coverage overlap in a cell-based communication system, wherein the aforementioned
5 disadvantages may be alleviated.

Statement of Invention

In accordance with a first aspect of the present
10 invention there is provided a method of determining coverage in a cellular communication system, as claimed in Claim 1.

In accordance with a second aspect of the present
15 invention, there is provided a storage medium, as claimed in Claim 10.

In accordance with a third aspect of the present
invention, there is provided a communication system, as
20 claimed in Claim 11.

In accordance with a fourth aspect of the present
invention, there is provided a communication unit, as
claimed in Claim 12.
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In summary, the inventive concepts of the present invention propose a mechanism for using measurement reports (MRs) to determine the unique coverage and the potential interfering (overlapping) coverage generated by each cell, preferably determined in terms of Erlangs. By utilising MRs in this manner, the Network Operator is able to direct and prioritise both automatic and manual maintenance and optimisation activities, for example, alarm prioritisation to distinguish the more critical coverage cells. Alternatively, or in addition, the coverage calculations, according to the preferred embodiment of the present invention, may be used to re-configure a system's operational parameters, such as: transmit power, a beam-forming antenna tilt or direction, and even turning off cell sites whose excessive coverage overlap provides unacceptable interference or severely restricts the frequency allocation process.

Brief Description of the Drawings

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Exemplary embodiments of the present invention will now be described, with reference to the accompanying drawings, in which:

25 FIG. 1 illustrates a block diagram of a cellular radio communications system adapted to support the various inventive concepts of a preferred embodiment of the present invention;

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FIG. 2 illustrates a cell-based communication system adapted to support the various inventive concepts of a preferred embodiment of the present invention; and

5 FIG. 3 illustrates a flowchart of a method of determining an overlapping coverage area, and thereafter utilising such information, in accordance with a preferred embodiment of the present invention.

10 Description of Preferred Embodiments

The inventive concepts of the present invention propose a mechanism for using measurement reports (MRs) to determine both the unique and overlapping (and therefore
15 interfering) coverage generated by each cell. In particular, three aspects of a respective cell's coverage may be determined:

(i) The amount of traffic that receives coverage uniquely from this cell;

20 (ii) The amount of traffic that receives coverage from this cell, but which could also obtain coverage from an adjacent cell; and

(iii) The amount of traffic carried by adjacent cells that could provide coverage to this cell.

25 From a perspective of a serving cell, at one extreme, it is known that the coverage area of the cell may be completely overlapped by one or more adjacent cells. At the other extreme, the coverage area of two cells may be
30 configured to not overlap at all. This variation has significant implications for system operation. For example, if a cell goes off-air, then subscriber units in the area uniquely covered by this cell will no longer have service. However, if there is a large degree of

overlap from neighbouring cells, then many subscriber units will be able to receive service from neighbouring, but less-preferred, cells. Conversely, with no overlap, all subscriber units will lose service.

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Hence, in accordance with a preferred embodiment of the present invention, a mechanism to determine an accurate knowledge of coverage overlap is proposed. Once an accurate knowledge of coverage overlap has been
10 determined the relative importance of keeping various cells on air can be identified.

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The inventors of the present invention have appreciated that those cells providing the most unique coverage are the most critical to be maintained. Therefore, for
example in a first embodiment of the present invention, the resulting cell outage alarm should be set to reflect the uniqueness and importance of the cell. Furthermore, in a second embodiment of the present invention, such
20 knowledge also helps determine network availability as well as enabling a Network Operator to set optimum system parameters. Furthermore, such knowledge enables higher capacity and better quality frequency plans to be deployed.

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From a perspective of a neighbouring, overlapping cell, at one extreme, the cell may overlap with many neighbouring cells. Alternatively, the cell may overlap with no other cells. This variation impacts frequency
30 planning, since the frequencies assigned to a cell with large overlap cannot be re-used in the overlapped cells, making frequency planning more difficult. However, a cell with a large overlap may be useful for providing

continuity of service, should the overlapped cells go out of service or become congested.

The inventive concepts of the present invention alleviate the aforementioned problems associated with the coverage prediction by extending the concept of an Intelligent Optimisation Service (IOS), as described later. In particular, the present invention proposes a mechanism of using existing measurement reports to assist in determining a level of coverage overlap. Furthermore, once such measurement reports have been received and processed and coverage overlap information has been calculated, the information can be used in a variety of ways, as detailed later.

Referring first to FIG. 1, a cellular telephone communication system 100 is shown, in outline, supporting a Global System for Mobile communication (GSM) air-interface, in accordance with a preferred embodiment of the invention. The European Telecommunications Standards Institute (ETSI) has defined the GSM air-interface.

Generally, the air-interface protocol is administered from base transceiver sites, within the network architecture 110, that are geographically spaced apart - one base site supporting a cell (or, for example, sectors of a cell), as shown in FIG. 2.

A plurality of subscriber units 112-116 communicate over the selected air-interface 118-120 with a plurality of base transceiver stations (BTS) 122-132. A limited number of MSs 112-116 and BTSs 122-132 are shown for clarity purposes only. The BTSs 122-132 may be connected to a conventional public-switched telephone network

(PSTN) 134 through base site controllers (BSCs) 136-140 and mobile switching centres (MSCs) 142-144.

Each BTS 122-132 is principally designed to serve its
5 primary cell, with each BTS 122-132 containing one or more transceiver units and communicating 156-166 with the rest of the cellular system infrastructure

Each BSC 136-140 may control one or more BTSs 122-132,
10 with BSCs 136-140 generally interconnected through MSCs 142-144. Processes within the MSCs are provided to account for the situation where a MS (112-116) passes between two BTS serving areas, for example MS 112 moving from an area covered by BTS 122 to an area covered by BTS
15 124, where the two BTSs are controlled by different BSCs (BSC 136 and BSC 138 in this example).

Similar processes are supported in MSCs to account for the situation where an MS moves between serving BTSs
20 where these BTSs are connected to different MSCs. These mechanisms therefore allow the cellular telephone communication system to support handover of MSs 112-116 between overlapping cells in a contiguous, seamless manner.

25 Each MSC 142-144 provides a gateway to the PSTN 134, with MSCs 142-144 interconnected through an operations and management centre (OMC) 146 that administers general control of the cellular telephone communication system
30 100, as will be understood by those skilled in the art.

The various system elements, such as BSCs 136-138 and OMC 146, include control logic 148, 150, 152, with the various system elements usually having an associated

memory function 157 (shown only in relation to OMC 146 for the sake of clarity). A memory function 157 of the OMC 146 typically stores historically compiled operational data as well as in-call data, system
5 information such as neighbouring cell-site lists and control algorithms such as a list of frequencies to be scanned by the respective MSs.

In accordance with the preferred embodiment of the
10 present invention, the OMC or an optimisation function adjunct to the OMC 146 receives Measurement Reports (MR) collected from respective cells, either from, say, serving BTSs and/or served MSs. In the context of the present invention, it is envisaged that an OMC's handling
15 of MRs may be complemented or replaced by any such adjunct optimisation function. As such, the following description of the OMC's functionality in this regard encompasses any such suitable configuration. Notably, the OMC 146 has been adapted to include an overlapping
20 coverage calculation function 155. The overlapping coverage calculation function 155 utilises the MR data to determine those cells that provide a unique coverage to MSs within those cells. The overlapping coverage calculation function 155 also utilises the MR data to
25 determine those cells where some coverage can be supported by neighbouring cells.

In this regard, the OMC is able to calculate an amount of overlapping coverage. The OMC 146 has been
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configured to receive any operational/ environmental data provided by the system elements or UEs relating to the operational characteristics of the respective cells, in order to determine, for example, a level of unique
5 coverage that respective cells provide.

In a further enhanced embodiment of the present invention, one or more BSCs 136 and/or one or more BTSs 122 may include, or be operably coupled to, an MR agent
10 (not shown). The BSC 136 or BTS 122 preferably configures the agent to seek out and record measurements for the requisite environmental or operational data that may affect the overlapping coverage area of the cell.

15 It is also envisaged that the cell's MR information may be sent from any number of sources and include any useful data. In particular, the information may include:

(i) Cell statistical information, available at the OMC, such as Congestion, Blocking, Mean-Hold Time
20 (MHT), Handover (HO) Cause distribution;
(ii) Measurement Reports, which indicate the Radio Frequency (RF) environment of the subscriber units;
or

(iii) Control Signalling behaviour. This
25 information is readily available to the OMC function in existing systems. It forms the basis of reports generated for the Network Operator to analyse during the course of normal operational activities.

30 In particular, if a MR from a MS contains no neighbouring BTS measurements, or only very weak neighbour measurements, it can be assumed that the MS could not achieve service from any neighbouring cell. This

information is particularly useful to the OMC 146, should that serving cell go off-air or become congested.

Conversely, if the MR contains one or more neighbour
5 measurements indicating a strong received signal, then it can be assumed that the MS could obtain service from one of these neighbours, if its serving cell becomes unavailable. Thus, by analysing all the MRs collected from a particular cell, it is possible to determine, for
10 example, a proportion of the cell's traffic that depends solely on that cell for service. In this context, the OMC 146 is able to determine a unique coverage factor for that cell (UCF), where:

$$15 \quad UCF = \frac{\text{Sum of MRs with no/weak neighbours}}{\text{Total Sum of MRs}} \quad [1]$$

In the context of the present invention, a weak neighbour is defined, for example, as a neighbour reported with a
20 received signal level (RXLEV) of < 'X', where 'X' can be set by the Network Operator, for example, set at an RXLEV of '10' (equivalent to, say, -100dBm).

In the enhanced embodiment of the present invention, the
25 OMC 146 comprises an overlapping coverage calculation function 155 to generate/calculate a subscriber-based coverage map that particularly indicates coverage overlap.

30 Preferably, the calculation to determine the degree of overlapping coverage is based on the number of times that a cell is reported as a neighbouring cell, by subscriber units in the other network cells. Indeed, in accordance with the preferred embodiment of the present invention,

this information can easily be extracted from existing measurement report information. In this regard, a carrier-to-interference (C/I) matrix of rows and columns is produced, where each column represents the potential
5 interference generated by a specific cell.

A simplified example of such a matrix is illustrated below in Table 1. The rows represent the cells 'A'-'D' as serving cells, and the columns represent cells 'A'-'D' as interfering cells. For example, cell 'B' can expect
10 to lose six Erlangs of traffic due to interference, if it has the same frequency as cell 'C'. Hence, the amount of coverage overlap generated by each cell, which could potentially lead to interference, is represented by the
15 total of the column for the respective cell. Thus, in this example, Cell 'B' has the highest overlap with forty Erlangs of traffic seen in other cells at a strong level.

Table 1:

	A	B	C	D
A		10	5	10
B	12		6	10
C	5	15		17
D	7	15	5	
Total	24	40	16	37

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Advantageously, the use of Measurement Reports ensures that 'real' measurement data from the actual operating network is used, in contrast to the known technique of
25 using inaccurate prediction data. By ensuring that a statistically significant volume of Measurement Reports are used in the calculations, it is possible to guarantee that the resulting measures or calculations of unique cell coverage and cell overlap are extremely accurate.
30 These values represent the cell coverage and overlap from

the perspective of all the network subscriber units. Consequently, the impact on the network subscriber units, of decisions made using this data, can be accurately determined.

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In accordance with the preferred embodiment of the present invention, the memory element 157 of the OMC 146 has also been adapted to include, for example, a look-up table of the coverage overlap information. In this regard, the look up table contains information relating to one or more of the following:

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- (i) Cell operational parameters,
- (ii) Threshold values used in the respective cell(s),
- 15 (iii) Traffic profile information for that cell,
- (iv) Received signal level information, say from a number of MSs, for that cell - irrespective of whether the MSs are being currently served in that cell, or
- (v) Transmitter power information, for either BTS
- 20 and/or MS, relating to a particular cell.

Although the inventive concepts of the present invention have been described with regard to an implementation in an OMC 146, it is within the contemplation of the invention that the overlapping coverage calculation function 155 may be provided in a separate device or function, operably coupled to the OMC 146.

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Alternatively, the overlapping coverage calculation function 155 may be located within any other element within the infrastructure, such as MSCs 142, 144, or

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distributed within a number of elements, if appropriate. For example, the overlapping coverage calculation function 155 could be implemented within the radio access network (RAN) of the cellular infrastructure equipment and/or it may be implemented as a stand-alone
5 element/function on an adjunct platform. Indeed, it is envisaged that the OMC as a logical entity could comprise several distributed or substantially co-located boxes with specific functions, including an optimisation (IOS)
10 box.

In a preferred embodiment of the present invention, it is also envisaged that one or more BTSs 122-132, and/or one or more BSCs 136-140 may be adapted to regularly or
15 intermittently collect the MR data. This information would then be forwarded to the OMC 146 (or indeed any other associated element) where the overlapping coverage area mapping/calculation function 155 resides.

20 More generally, an overlapping coverage calculation function 155 may be programmed into, say, the OMC 146 according to the preferred embodiment of the present invention, in any suitable manner. For example, new apparatus may be added to a conventional communication
25 unit (for example OMC 146). Alternatively existing parts of a conventional communication unit may be adapted, for example, by reprogramming one or more processors therein. As such the required adaptation may be implemented in the form of processor-implementable instructions stored on a
30 storage medium, such as a floppy disk, hard disk, programmable read only memory (PROM), random access memory (RAM) or any combination of these or other storage media.

Referring now to FIG. 2, a cell-based communication system 200, adapted to support the various inventive concepts of a preferred embodiment of the present invention, is illustrated. FIG. 2 is a representation of, say, a street level coverage map from Cells A 210, B 220, C 230, D 240, E 250, F 260 and X 270. As with a vast majority of cell-based wireless communication systems, there is significant degree of overlap between cell coverage areas. A key illustration in FIG. 2 is that although the coverage area of Cell X 270 is significant, most of its coverage could be supplemented by coverage from neighbouring cells 'A' to 'F' 210-260. The proportion of unique coverage that is solely supportable by cell X 270 is an island of coverage at the centre of cell X 270. Any subscriber units located in this region would definitely suffer a complete outage if Cell X 270 were to go out of service.

Although FIG. 2 illustrates the geographical coverage impact of such an outage, a key benefit of the present invention is to determine a number of Erlangs of traffic that would be lost due to the outage. For example, let us assume that only 10% of the cell's coverage area is uniquely served by this cell.

However, if all the subscriber units in the cell are concentrated in this one small central area, then the impact of a cell outage will be to remove service from 100% of the cell's traffic, not just 10% that relates to the geographical impact. Thus, it is the Erlang value related to impacted traffic that is preferably used in, for example:

- (i) Prioritising a resulting outage alarm, and/or

(ii) Re-configuring a system's operational parameters.

In an enhanced embodiment of the present invention, the
5 potential interference generated by cell X 270 on
neighbouring cells 'A'-'F' 210-260, based on a level of
overlap between the cells, may be used to determine
whether to re-configure cell X's operational parameters.
For example, the transmit power of cell X 270 may be
10 reduced, or antenna down-tilting of Cell X's beam-forming
antenna introduced.

Referring now to FIG. 3, a flowchart 300 illustrates an
overview of the preferred overlapping coverage
15 measurement process. The flowchart commences with an OMC
(or other box) collecting a series of Measurement Reports
(MRs), for example resulting from a subscriber unit
polling operation, as shown in step 305. MRs are
collected from the target cell and from its neighbouring
20 cells.

These MRs are then separated into, say, three categories,
in step 310:

- (i) Those MRs for which an alternative cell is
25 identified as being able to provide coverage;
- (ii) Those MRs for which there is no alternative
coverage option, i.e. the subscriber unit generating the
MR can only be served by that cell in that location; and
- (iii) Those MRs collected from neighbouring cells
30 that show a strong level of coverage from the target
cell.

The OMC then converts the MR information into Erlangs, in
step 315, to determine the traffic impact, rather than

the geographical impact, of any potential cell outage. These results may then be stored, in step 325, according to the time of day, day of the week, month and any additional cell parameter information such as transmit
5 power, and subscriber unit information such as cell location (say, from a GPS unit). In the illustrative step 325, the results are stored against four-hour intervals for each day of the week: however clearly the results may be stored using any storage/sorting method
10 determined by a skilled person.

Thus, in this manner, an OMC determines how much traffic coverage is uniquely provided by a particular cell, for example, using existing measurement report data.
15 Preferably, a statistically valid sample of MRs is used in the determination of overlapping and/or unique coverage. Once an Erlang figure has been determined, this figure is used to influence the Network Operator (or the OMC) to improve the network's performance.

20 For example, the figure is used to determine an appropriate cell outage strategy, in step 330. It is envisaged that such a use may entail determining when and how to maintain a cell, i.e. by turning the cell off.
25 The traffic impact of such cell maintenance can therefore be minimised. Furthermore, the cell outage strategy may encompass the OMC using the Erlang value of uniquely covered traffic to select an alarm priority setting for the cell, as shown in step 340.

30 Advantageously, the unique coverage capability and coverage overlap information of the cell can also be used to automatically re-configure operational parameters in a cell, as shown in step 335. Such a re-configuration of

operational parameters helps determine and implement a feasibility of beam-forming changes such as down-tilts, provision of additional redundancy, etc.

- 5 The inventive concepts of the present invention utilise dynamic monitoring and adaptation of a cell's operational parameters. Such information, when obtained extensively throughout the system, may be assessed to better plan and utilise available communication resources (frequencies) throughout the system. In this manner, it is envisaged that an automatic frequency planning operation may benefit from the inventive concepts described herein.

- 15 It is within the contemplation of the invention that the OMC 146 may use any additional indicia, such as traffic load, time of day, etc. to enhance the assessment of communications within the communication system. It is also envisaged that the OMC 146 (or other element) may poll BTSs or MSs within the system to obtain such additional indicia. Further variations that fall within the inventive concepts herein described will be apparent to a person skilled in the art.

- 25 The preferred embodiment of the present invention has been described with regard to a cellular telephony communication system, such as the global system for mobile communications (GSM). It is envisaged that the invention is equally applicable to other wireless communication systems, such as a universal mobile telecommunication system (UMTS), any code division multiple access (CDMA) or time division multiple access (TDMA) system, or an integrated digitally enhanced network (iDEN)[™] as supplied by Motorola[™]. It is also within the contemplation of the invention that

alternative radio communication architectures, such as private or public mobile radio communication systems could benefit from the inventive concepts described herein.

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It will be understood that the communication system, communication unit, and improved method for coverage prediction, as described above, provides at least some of the following advantages that could not be reliably obtained using existing coverage prediction methods:

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(i) Cells with high unique cell coverage are recognised as such, and may be managed more carefully. For example, a Network Operator may decide to introduce additional equipment redundancy into a particular system to minimise the risk of cell outage.

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(ii) Cells with low unique cell coverage can be configured to receive less attention. In some cases, if capacity is not required, it may even be desirable to switch the cell off.

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(iii) The aforementioned principles can be extended to encompass the level of unique coverage provided by a group of cells (e.g. a BSC area), or the level of unique coverage provided by a particular sub-layer or frequency band (e.g. a Micro-cell layer, or a cellular 1800 MHz frequency band)

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(iv) Cells that provide high levels of coverage overlap provide severe constraints on the development of a high quality and capacity frequency plan. Consequently, these cells can be examined to determine

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whether the cell's transmit power can be reduced, the antenna down-tilted, or the cell completely switched off.

5 Whilst the specific and preferred implementations of the embodiments of the present invention are described above, it is clear that a skilled artisan could readily apply variations and modifications of such inventive concepts.

10 Thus, a communication system, a communication unit, and a method for coverage prediction have been provided wherein the aforementioned disadvantages associated with prior art arrangements have been substantially alleviated.